Project no. **GOCE-CT-2003-505540**

Project acronym: **Euro-limpacs**

Project full name: **Integrated Project to evaluate the Impacts of Global Change on European Freshwater Ecosystems**

Instrument type: **Integrated Project**
Priority name: **Sustainable Development**

Deliverable No. 230
The relationship between sediment stability and macroinvertebrate community composition

Due date of deliverable: **Month 54**
Actual submission date: **30/01/2009**

Start date of project: **1 February 2004** Duration: **5 Years**

Organisation name of lead contractor for this deliverable:
ALTERRA (the Netherlands) – Piet Verdonschot

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)

Dissemination Level (tick appropriate box)		
PU	Public	Pu
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

The relationship between sediment stability and macroinvertebrate community composition

A. M. Siedlecka
R.C.M. Verdonschot
M.W. van den Hoorn
P.F.M. Verdonschot

P.O. Box 47; 6700 AA Wageningen; The Netherlands
Phone: + 31 317 480700; fax: +31 317 419000; e-mail: info.alterra@wur.nl

Contents

Acknowledgements

This study was part of the European Framework 6 Program EUROLIMPACS, funded by the European Union under project number GOCE-CT-2003-505540. We thank Rink Wiggers for help with the identifications.

Funded by the European Union, Framework Programme 6, Theme 1.1.6.3 “Global Change and Ecosystems" EUROLIMPACS contract no. GOCE-CT-2003-505540.

Summary

Changes in seasonal patterns of precipitation due to climate change are a serious threat to stream ecosystems, by increasing frequency of high flows and flooding, low flows and drought, and fast changes in flow or flow dynamics. Disturbances as a result of high flows or high current velocity have been suggested to be one of the dominant factors determining stream macroinvertebrate community composition.

Local substrate instabilities occur frequently in lowland streams, nevertheless increased magnitude, frequency or duration of floods due to heavy precipitation events result in instabilities of far greater size and magnitude. Those disturbances impact macroinvertebates directly, by removing individuals from the stream bed or damaging them in the shifting sands, or indirectly by removing food resources and shelters.

We studied the effects of stream bed instability, expressed as amount of transported material per 24 hours and organic matter content of the stream bed, on macroinvertebrate community composition in two sandy lowland streams in the Netherlands. There was a relationship between substrate stability and macroinvertebrate community composition, but preferences differed among the dominant taxa. Oligochaeta (burrowers) were present in all sections, independent on the substrate stability, while *Gammarus* sp. (swimmer) were the most abundant in stream sections with little sediment transport and a high percentage of organic matter. Among clingers/climbers, preferences differed per taxon: *Polypedilum scalaenum* (herbivore) was most abundant in stable stream sections, while *Dugesia gonocephala* (carnivore) did not have a clear preference. This difference was probably caused by differences in food sources between groups. Abundance of carnivorous *Eloeophila* sp was not related to substrate stability.

Based on our study, we can conclude that at least part of the dominant macroinvertebrate taxa preferred stable stream sections. Increase in size and magnitude of floods, resulting in a larger proportion of instable sediment, could therefore negatively influence these groups by reducing the area of suitable habitat. This in turn could have important consequences for stream ecosystem functioning.

1 Introduction

Changes in seasonal patterns of precipitation due to climate change are a serious threat to stream ecosystems, because many ecological processes are influenced by the discharge regime of a stream (Carpenter et al. 1992, Allan 1995). These threats are related to three features, namely high flows and flooding, low flows and drought, and fast changes in flow or flow dynamics. Its ecological effects depend on the magnitude, frequency, duration, timing and rate of change (Gasith & Resh 1999, Poff et al. 1997). Disturbances as a result of high flows or high current velocity have been suggested to be one of the dominant factors determining stream macroinvertebrate community composition on various scales; on stream level as well as on microhabitat level (Reice et al. 1990).

Local substrate instabilities occur frequently in lowland streams, also under normal flow conditions, because the stream bed consists mainly of sand and organic material. Increased magnitude, frequency or duration of floods due to heavy precipitation events result in instabilities of far greater size and magnitude. Those disturbances impact macroinverterbates directly, by removing individuals from the stream bed, due to the increased current velocity or damaging them in the shifting sands. Indirectly the macroinvertebrate community is influenced because resources are removed (biofilm, algae, organic material) or refuge sites are washed away (McCabe & Gotelli 2000).

Many stream organisms are, to some degree, adapted to a life in running water. Various behavioural and morphological adaptations suited to withstand sediment movement and high current velocity are observed in stream macrofauna (Vieira et al. 2006). Some groups of species are able to withstand stronger currents or a higher degree of sediment movement/dynamics than others. They possess certain traits which enable them to survive extreme conditions, thereby decreasing the risk of being allocated or damaged during high flows. Other species, without those adaptations, disappear when a certain frequency, magnitude, duration, rate of change or timing of extreme events is exceeded. For these species, it is simply impossible to survive in those streams or stream sections.

To test the relationship between stream macroinvertebrate presence and substrate stability and the mechanisms which underlie these patterns, we monitored the stream bed of two sandy lowland streams in the Netherlands. We investigated if:

- There is a relationship between substrate stability and the presence of certain macroinvertebrates,
- It is possible to distinguish groups of organisms that due to various life history tactics live under different substrate stability conditions.

2 Materials and methods

In April, October and November 2007 three substrate stability experiments were performed. The first two experiments took place in the Springendal stream and the third experiment in the Heelsum stream. Both streams are shallow, lowland streams with a sandy bottom (Table 1).

Table 1: Characteristics of the streams selected for experiments

Stream	Land use spring	Land use experimental sections	Average width [cm]	Average depth [cm]
Springendal	natural	natural, agricultural	152	18
Heelsum	natural	urban	207	16

In each experiment a number of stable and unstable stream sections was selected (Table 2). Sections with little bed substrate movement and a large amount of deposited organic material were characterized as stable. Sections with frequent bed substrate movement and few patches of deposited organic material were characterized as unstable.

2.1 Streambed substrate methods

Sediment traps were used to measure the amount of transported material. Traps were composed of a plastic box (10cm x 10 cm x 12.5cm) covered by a PVC plate (20 cm x 22 cm) with a round opening in the middle (4 cm in diameter) (Figure 1). Through this opening sediment particles can settle down. At the downstream side the cover plate bended 30° downwards over a length of 7 cm. Sand grains were glued on the cover, to prevent erosion of the bed substrate around the trap (Figure 1). The cover on the boxes was secured to the stream bottom with 4 metal pins (30 cm long). Sediment traps were placed in the stream bottom with its opening on the sediment-water interface (Figure 2).

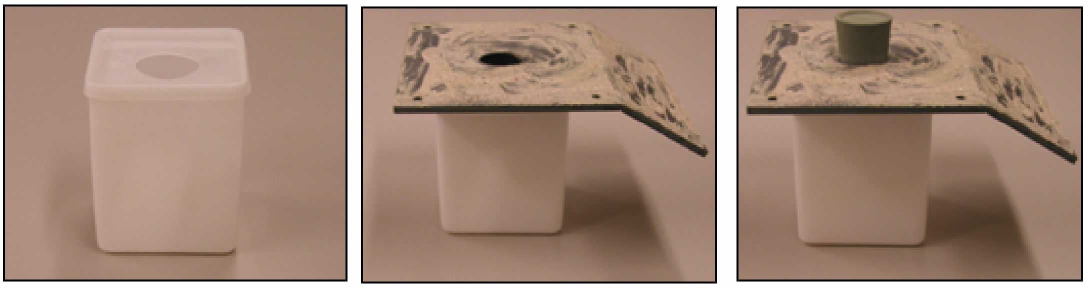

Figure 1: Sediment traps as used in the experiment. Box trap (left), operational box with sediment cover (middle), closed with a rubber cork for retrieval from the field (right).

Nine sediment traps per section were used in the first experiment. The traps were left closed with rubber corks for one week in order to allow the surrounding substrate to stabilize. Hereafter, the corks were removed and the traps were left open for 24 hours. In experiment 2 and 3 one trap per section was used. In these experiments initial stabilization time was shortened to one hour, because of an increase chance of erosion of the substrate around the traps due to discharge manipulations.

Figure 2: Sediment trap in the stream bed of the Springendal stream

After 24 hours, sediment traps were closed and transported to the laboratory, where the volume of collected substrate was measured with a 100 ml or 1000 ml cylinder, depending on the amount of collected material.

Additionally, a volume of approximately 400 ml of substrate was collected in each section upstream from the sediment traps, in order to determine the relative amount of organic material of the substrate. Samples were dried in an oven (105ºC) for 6 days until constant weight was reached, to determine the dry weight (DW). Next, the samples were ashed at 550ºC for 4 hours to determine the mineral content of the substrate.

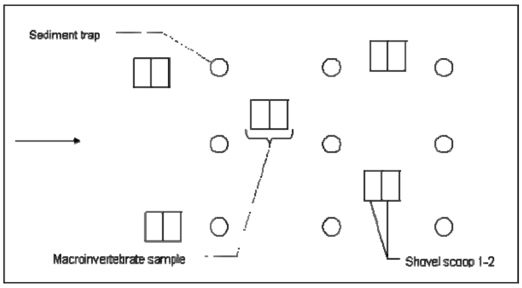

Figure 3a: Sampling design in experiment 1. Arrow indicates direction of flow.

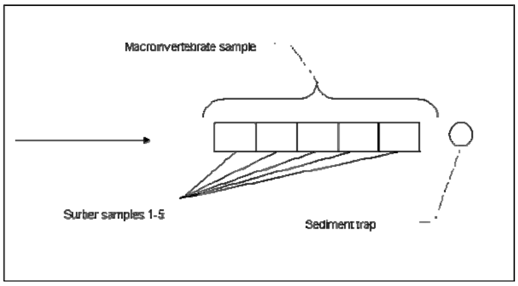

Figure 3b: Sampling design of experiments 2 and 3. Arrow indicates direction of flow.

2.2 Macroinvertebrate methods

In order to determine macroinvertebrate abundance and species composition in and on the stream bed, samples were taken near the sediment traps (Table 2). In the first experiment, randomly 5 samples were taken in each of the 6 sections (Figure 3a). Each sample consisted of 2 pooled scoops with a macrofauna shovel (7 cm x 15 cm; 0.015 m^2). In experiment 2 and 3, one sample per section was taken upstream of the sediment trap. Each sample consisted of a pooled series of five Surber sampler (mesh-size 200 µm, 13.5 cm x 14 cm x 2 cm; 0.0189 m^2) samples (Figure 3b).

Table 2: Experimental design of experiments 1 to 3

Experiment	Stream	Nr. of sections	Sediment traps per section	Macroinvertebrate samples per section	Sampling date
1	Springendal	6	9	5	02-04-2007
2	Springendal	12	1	1	09-10-2007
3	Heelsum	10	1	1	31-11-2007

In the laboratory the samples were decanted 10 times and sieved over a 250 µm mesh. Macroinvertebrates were sorted alive and preserved in 70% ethanol until further identification, except Oligochaeta and Hydracarina. The former were preserved in 4% formaline, the latter in Koenike fluid. Macroinvertebrates were identified to the lowest possible taxonomical level.

2.3 Data preparation and analyses

In some taxonomic groups not all individuals could be to identified to species level, but were identified to a higher taxonomical level, especially early instars and damaged material. To prevent taxonomical overlap in the database, which results in inconsistencies during the analysis, taxonomical data had to be transformed. The criteria described by Vlek et al. (2004) were used in the taxonomical adjustment process:

- when genus/family was identified mainly to the species level, genus/family was removed and only species remained in further analyses
- when the frequency of occurrence of the genus/ family was higher than 20% of all the species belonging to this genus, then the species were assigned to genus level
- when a taxon was present in different life stages (e.g. juveniles, pupae), they were aggregated to one taxon.

Pisidium sp was excluded from the analysis in experiment 2 because of improper sorting. In experiment 3, two out of ten sediment traps did not collect material. Data from these traps was not used in further analyses.

The two experiments from the Springendal stream were analyzed separately, since the experiments were preformed in different seasons (April – experiment 1 and October – experiment 2) and a different methodology, which could lead to differences in number of individuals and species collected.

Differences in the amount of transported sediment, percentage organic material in the sediment, total abundance, and total number of taxa were tested using Mann-Whitney U tests, t-tests or ANOVAs in SPSS 15.0 for Windows. The non-parametric tests were used when the criterion of normality and homogeneity of variances of the data was violated. Also the correlation between the amount of transported sediment and relative amount of organic material, total macroinvertebrate abundance, total number of taxa and abundance of the most abundant species was tested (Pearson Correlation coefficient, SPSS 15.0 for Windows).

In experiment 2 and 3, species were considered to be dominant if more than 20 individuals occurred in all samples from an experiment. In experiment 2 six dominant taxa were distinguished and used in further analyses: *Polypedilum scalaenum* (69% of the whole community), *Gammarus pulex* (23%), *Sericostoma personatum* (1%), *Eloeophila sp* (1%), and Tubificidae (with hair setae) (3%). In experiment 3 five taxa were dominant: *Gammarus sp* (58% of the whole community), *Aulodrilus japonicus* (4%), Tubificidae (with hair setae) (14%), Lumbriculidae (4%), and *Pisidium sp.* (5%). Rare taxa were not analyzed separately.

Differences between macroinvertebrates community composition of the samples were analyzed using principal component analyses in CANOCO for Windows 4.5.

3 Results

3.1 Springendal – experiment 1

Due to erosion of the stream bed in the first experiment, data from two sections were considered as unreliable and were therefore excluded, resulting in a total of 4 sections which could be analysed further.

Based on the amount of transported sediment, three sections were considered stable, with a low volume of transported sediment (on average 11 to 53 ml in 24 hours). In one section much more sediment transport occurred (on average 752 ml in 24 hours), and was therefore considered unstable. The percentage organic material in the stream bed showed much variation, especially in section 1 and 3 (Figure 3).

Total macroinvertebrate abundance differed significantly between the sections (One-way ANOVA: F=3.821, df=3, α=0.05, p=0.031) with a significant difference between section 2 (stable) and section 4 (unstable) (Tukey HSD test $p<0.05$). Number of taxa differed significantly between section 2 (stable) and section 4 (unstable) (Mann Whitney U test, Z=-2.685, α=0.0125 Bonferroni-corrected n=4, p=0.007) (Table 3)

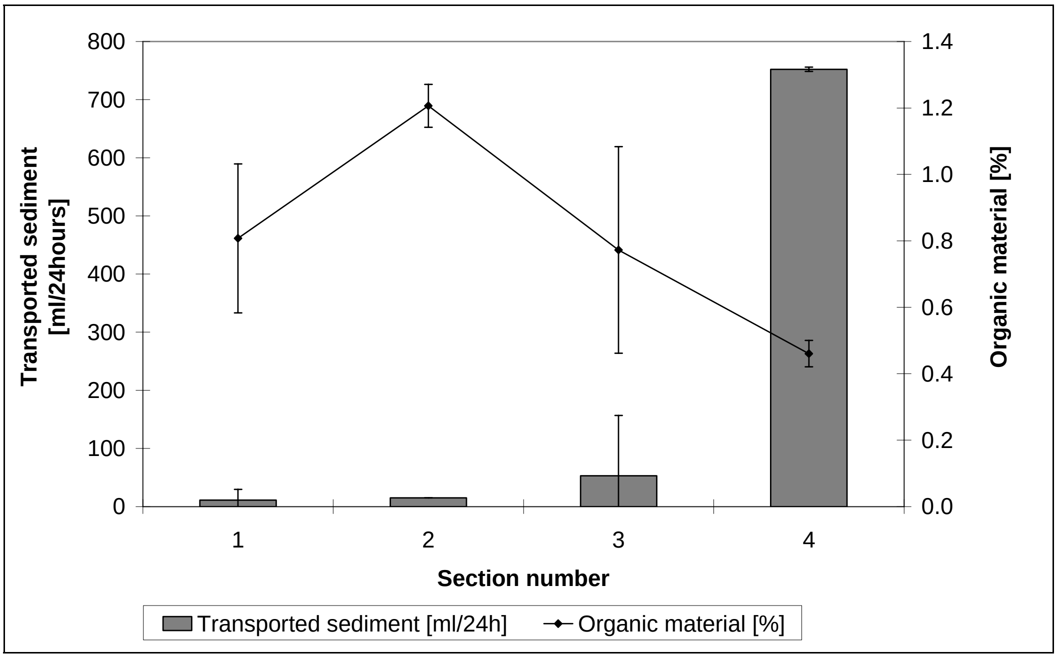

Figure 3: Volume of transported sediment in 24 hours and relative amount of organic material of the stream bed per stream section in experiment 1. Error bars represent 1 standard deviation.

Table 3: Average macroinvertebrate abundance and number of taxa collected in experiment 1 ±1 standard error

Section	Average abundance per sample	Average # taxa per sample
1	23.6 (±7.5)	3.4 (±0.9)
2	24 (±4.5)	4.6 (±0.4)
3	13.8 (±2.0)	4.2 (±0.7)
4	5 (±2.2)	1.6 (±0.2)

Using detrended correspondence analysis (DCA), the maximum length of gradient was determined for the macroinvertebrate dataset of experiment 1, which was 2.692. This indicated that the data was probably best described using a linear technique, in this case a principal component analysis (PCA). Volume transported sediment and percentage of organic material of the stream bed were used in the analysis as supplementary variables. First axis of the PCA (eigenvalue 0.560) explained 56% of the variation in the dataset, and was correlated to the percentage organic material of the stream bed. Second axis explained another 17.8% (eigenvalue 0.177), followed by the third 12.6% (eigenvalue 0.126) and the fourth 6.6% (eigenvalue 0.066). In the ordination section 2 appeared to correspond to a high percentage organic material in the sediment (Figure 4).

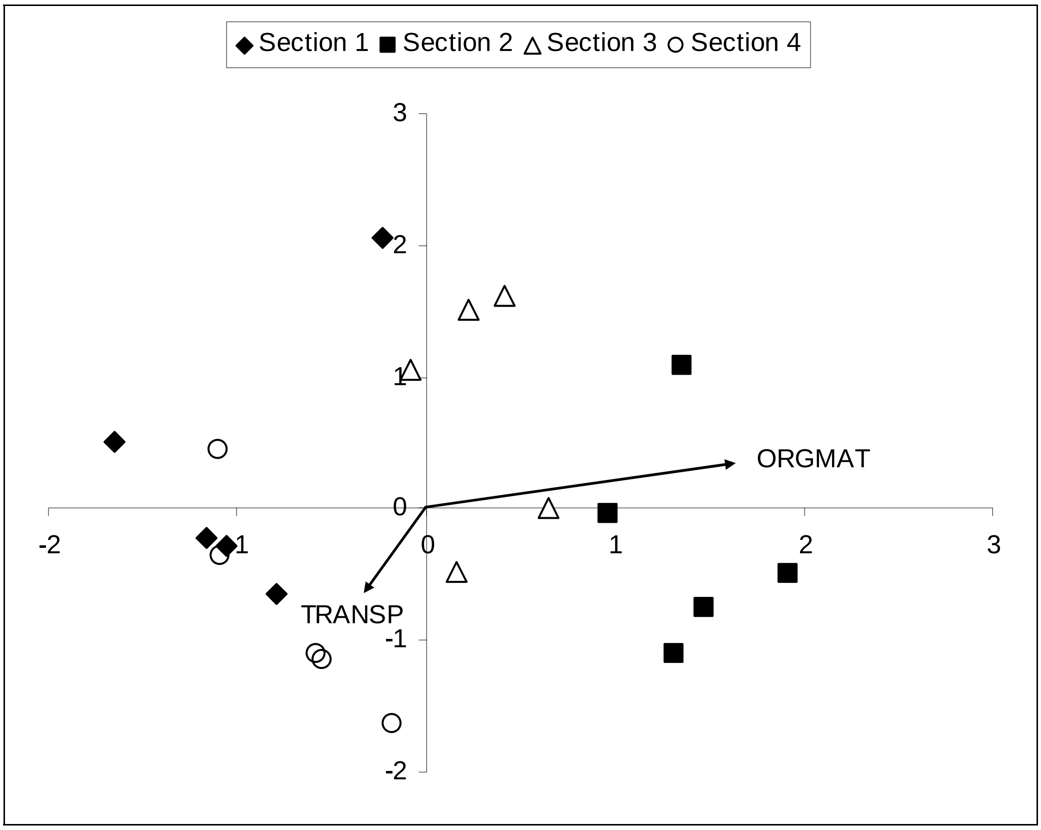

Figure 4: PCA ordination diagram of experiment 1 (axis 1 horizontal and axis 2 vertical), with volume of transported sediment (TRANSP, ^{10}Log transformed) and percentage organic material in sediment (ORGMAT) as supplementary variables. Symbols indicate samples which belong to one section.

In samples of section 4, the section with the largest volume of transported material in 24 hours, the chironomid *Polypedilum scalaenum* was dominant, but this Chironomidae was also found, in even higher numbers, in the stable section 3. Section 2, with the highest percentage of organic material in the sediment, contained relatively high numbers of the amphipod *Gammarus pulex*, the tricopteran *Sericostoma* sp., and the bivalve *Pisidium* sp were found. Sericostoma was also common in section 1 (Table 4).

Table 4: Total number of individuals per taxon per section of the Springendal stream in experiment 1.

Taxon	Group	Section 1	Section 2	Section 3	Section 4
Agapetus fuscipes	Trichoptera	1			
Lumbriculidae	Oligochaeta		1		
Neolimnomyia sp.	Diptera	1			
Ceratopogonidae	Diptera		2		
Dicranota sp.	Diptera			1	
Tubificidae	Oligochaeta				1
Paracladopelma sp.	Chironomidae	3		2	
Eloeophila sp.	Diptera	5	13	4	1
Pisidium sp.	Bivalvia		30	5	1
Gammarus pulex	Amphipoda	12	20	13	1
Sericostoma sp.	Trichoptera	32	54	1	
Polypedilum scalaenum	Chironomidae	15		92	21
Total # individuals		69	120	118	25
Total # taxa section		7	6	7	5

3.2 Springendal – experiment 2

The percentage of organic material present in the sediment of the stream sections was significantly negatively correlated to the amount of transported sediment in that section (Pearson Correlation Coefficient -0.874, $\alpha=0.05$, $p=0.01$) (Figure 5).

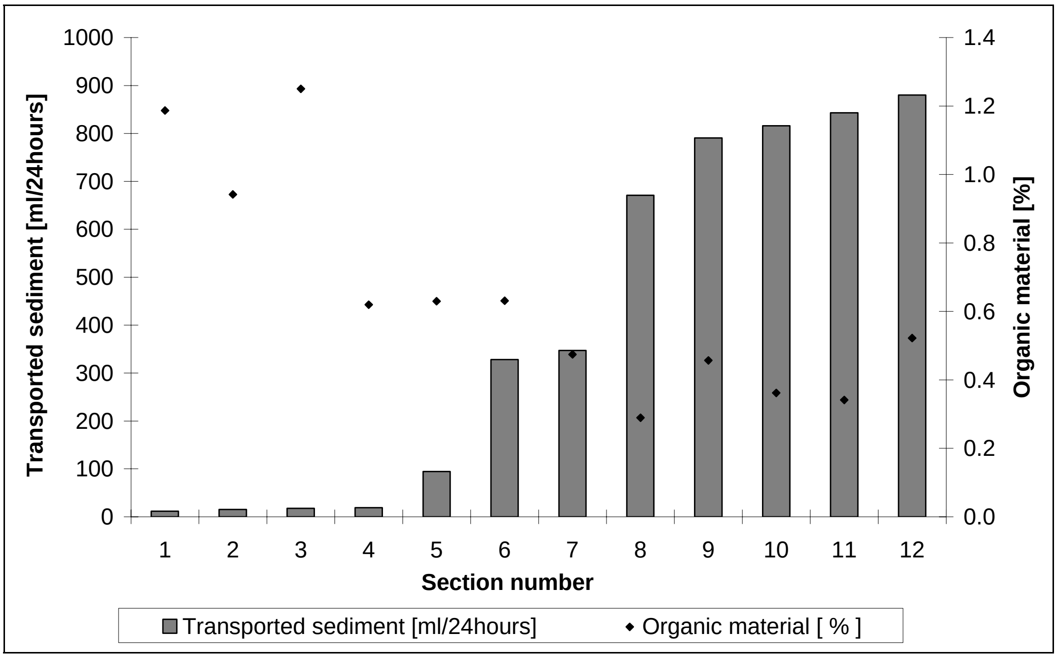

Figure 5: Volume of transported sediment and percentage of the organic material in the sediment per section in experiment 2.

In the PCA analysis of the macroinvertebrate data, with transported sediment and relative amount of organic material as supplementary variables, the first axis (eigenvalue 0.532) explained 53.2% of the variation in species data. First axis was correlated with a gradient in the amount of transported material and percentage organic material in the sediment (Figure 6). The second axis (eigenvalue 0.201) explains another 20.1%. In the ordination diagram, distribution of samples along the second axis is noticeable, which indicates that there is another important factor influencing the macroinvertebrates composition besides the substrate stability. Percentage variance explained by the third (eigenvalue 0.101) and fourth axis (eigenvalue 0.059) was relatively low, respectively 10.1% and 5.9%.

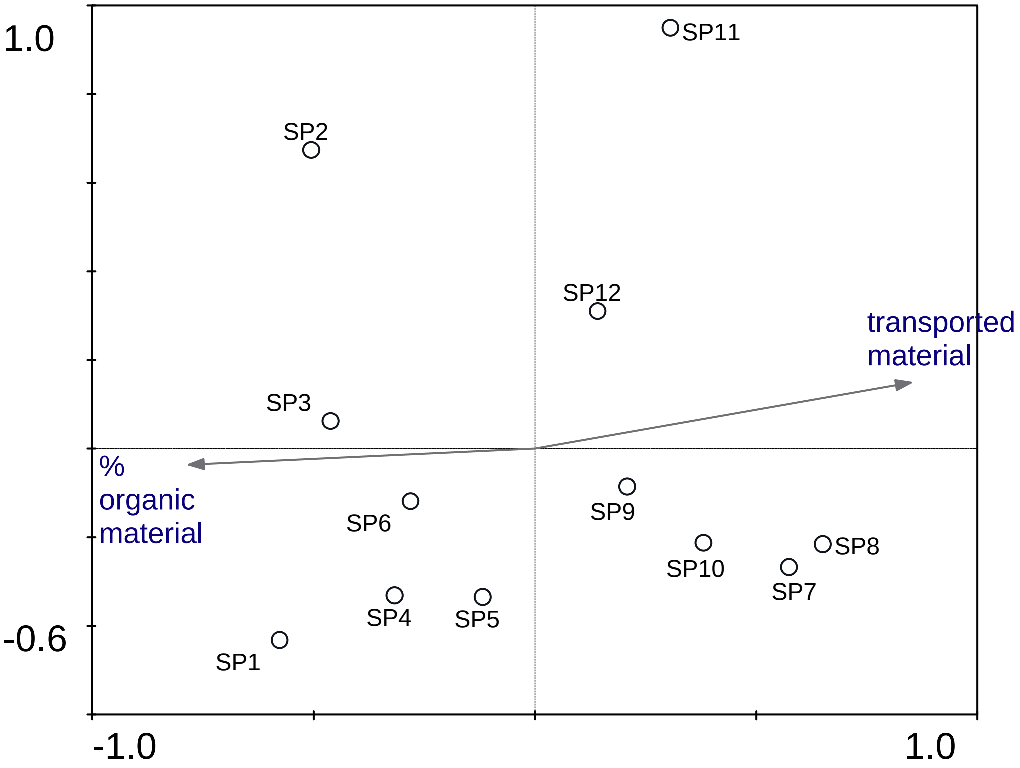

Figure 6: PCA ordination diagram of experiment 2 (axis 1 horizontal and axis 2 vertical), for stream sections 1 – 12 (numbers in diagram) of the Springendal stream.

Abundance of *Sericostoma personatum, Gammarus pulex, Eloeophila* sp., and *Polypedilum scalenum* increased with an increase in the percentage of organic material of the sediment. Several taxa (e.g. Tubificidae, both with and without hair setae, *Dugesia gonocephala*, and Lumbriculidae) are correlated to the second canonical axis (Figure 7). Their distribution was not dependent on sediment stability, but appeared to be influenced by another factor.

Total macroinvertebrate abundance was significantly negatively correlated to the volume of transported sediment (Pearson Correlation Coefficient = -0.662, α=0.05, p=0.05) and positively correlated to the percentage of organic material in the sediment of the sections (Pearson Correlation Coefficient = 0.741, α=0.05, p= 0.01), while number of taxa did not show a significant correlation with any of the factors (p> 0.05 for all).

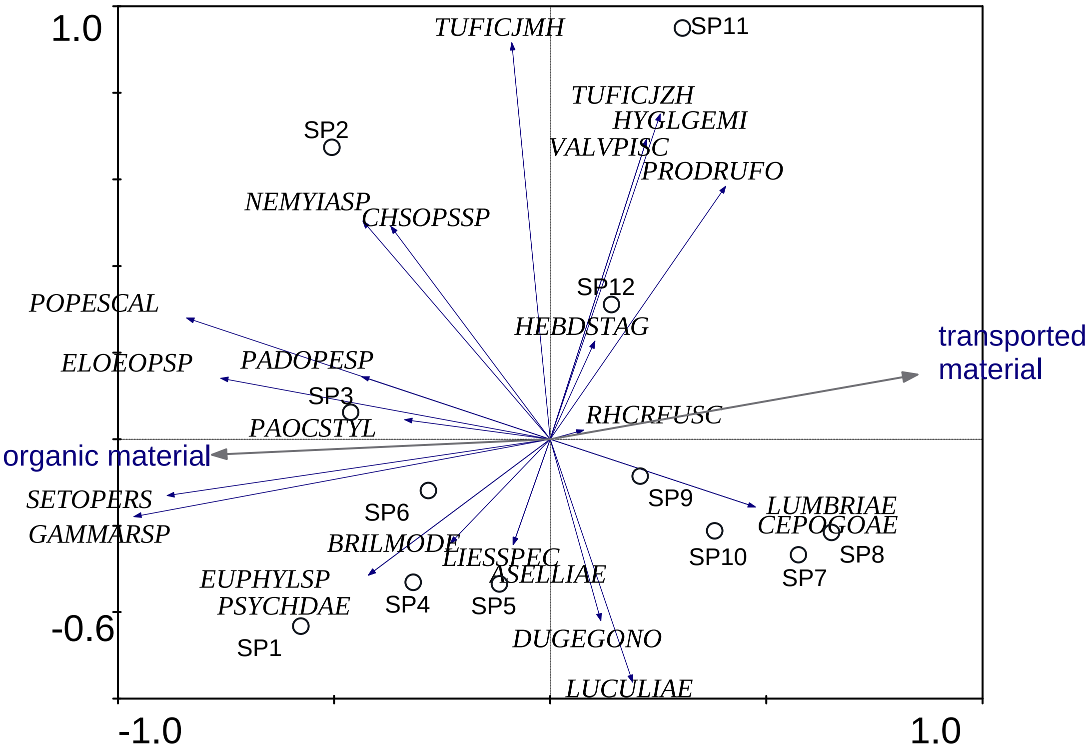

Figure 7: PCA ordination diagram of taxa and samples with axis 1 (horizontal) and axis 2 (vertical). See appendix 1 for abbreviations of the taxonnames.

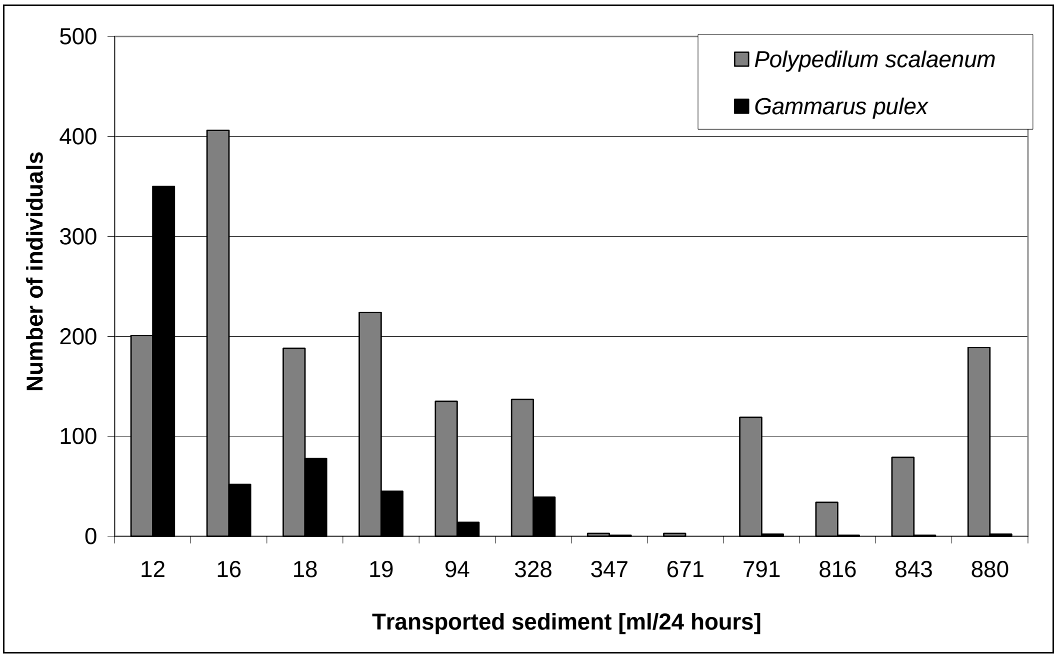

Figure 8: Springendal – experiment 2. Abundance of *Polypedilum scalaenum* and *Gammarus pulex* per section in relation to the volume of transported sediment in that section.

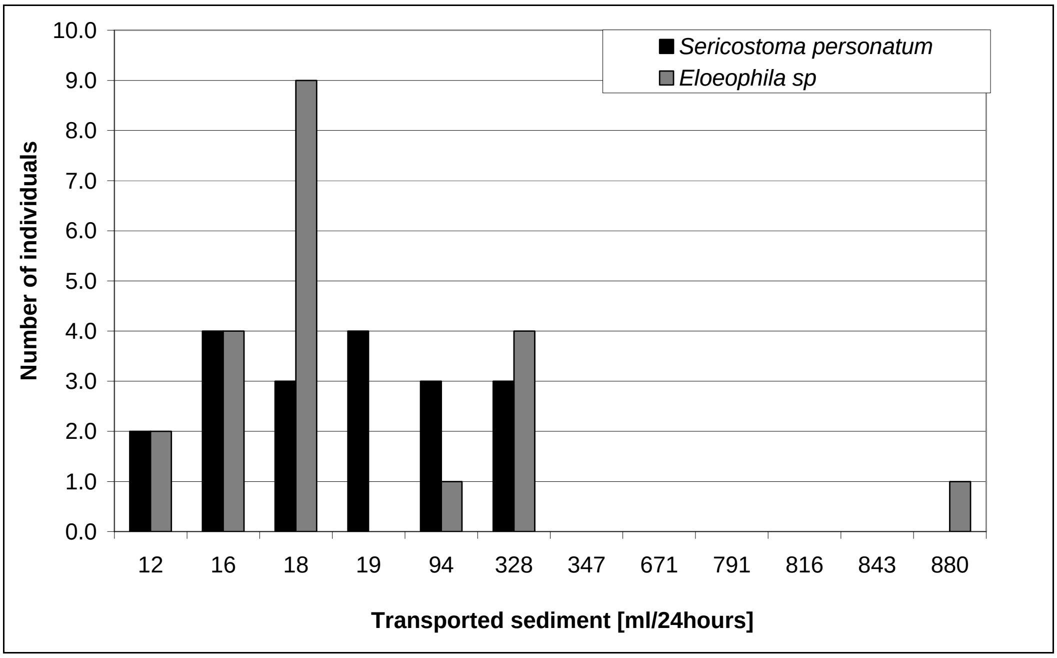

Figure 9: Springendal – experiment 2. Abundance of *Sericostoma personatum* and *Eloeophila* sp. per section in relation to the volume of transported sediment in that section.

Abundance of three of the six most abundant taxa was significantly negatively correlated to the volume of transported sediment (*Gammarus pulex* Pearson Correlation Coefficient = -0.896, $p<0.01$, *Eloeophila* sp. Pearson Correlation Coefficient = -0.589, $p<0.05$, *Sericostoma personatum* Pearson Correlation Coefficient = -0.87, $p<0.01$) and positively correlated to the percentage of organic material in the sediment (*Gammarus pulex* Pearson Correlation Coefficient = 0.913, $p<0.01$, *Eloeophila* sp Pearson Correlation Coefficient = 0.830, $p<0.01$, *Sericostoma personatum* Pearson Correlation Coefficient = 0.736, $p<0.01$). *Polypedilum scalaenum* abundance was correlated to the percentage of organic material in the sediment of that section Pearson Correlation Coefficient = 0.608, $p<0.05$) but not to the volume of transported sediment ($p>0.05$). Tubificidae (with hair setae) and *Dugesia gonocephala* did not show any significant correlations ($p>0.05$ for all).

3.3 Heelsum – experiment 3

In the Heelsum stream there was a significant difference in volume of transported sediment between sections 1-4 and 5-8 (T-test, t(4)= -7,12; $p< 0.01$). The percentage organic material in the sediment did not differ ($p> 0.05$) and did not show a correlation with the amount of transported sediment ($p > 0.05$) (Figure 10).

In the PCA ordination of the macroinvertebrate taxon composition of the sections in the Heelsum stream, transported sediment and relative amount of organic material were used as supplementary environmental variables. In the PCA ordination diagram samples are located along the first canonical axis, which explains 45,5% of variance in the species data (eigenvalue 0.455) (Figure 11). Samples with the lowest amount of transported sediment and highest relative content of organic material (samples 1-3) are located on the right side of the diagram. Based on species composition, sample 4 is placed on the left side of the diagram, which appears to be associated with more disturbed samples. The second axis (eigenvalue 0.204) explains another 20.4%. In the ordination diagram, distribution of samples along the second axis is noticeable, which indicates that there is another important factor influencing the macroinvertebrates composition besides the substrate stability. Percentage variance explained by the third (eigenvalue 0.151) and fourth axis (eigenvalue 0.081) was lower, respectively 15.1% and 8.1%.

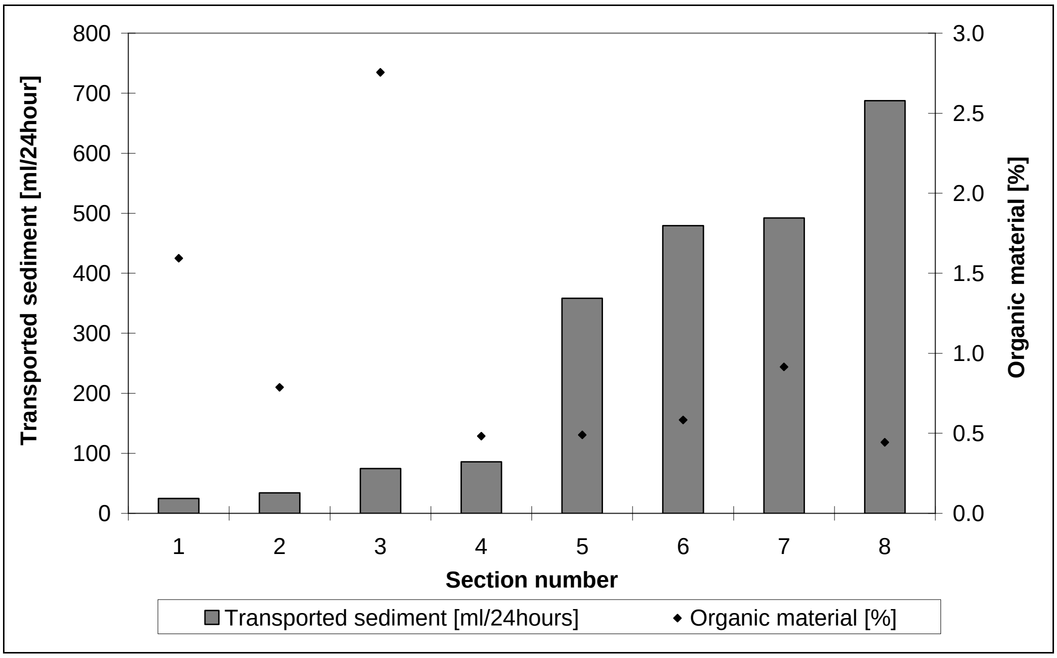

Figure 10: Heelsum – experiment 3. Volume of transported sediment and percentage organic material in the sediment per section.

The PCA ordination of the taxa – samples relation (Figure 12) showed that many taxa are correlated with the first canonical axis and were found in samples 1-3. This axis is highly correlated to sediment stability (both percentage organic material and volume of transported sediment). Additionally, a high correlation to the second canonical axis is noticeable for a number of species, which suggests that there is another environmental factor influencing the community besides the sediment stability.

There was no correlation between the volume of transported sediment and the total macroinvertebrate abundance ($p>0.05$), nevertheless abundance was significantly positively correlated to the percentage of organic material in the sediment (Pearson Correlation Coefficient = 0.78, $p<0.05$). Number of taxa was correlated to the volume of transported sediment (Pearson Correlation Coefficient = 0.784, $p<0.05$) and percentage organic material (Pearson Correlation Coefficient = 0.847, $p<0.01$) in the sections.

Gammarus sp. showed a significant negative correlation to the volume of transported sediment (Pearson Correlation Coefficient = 0.784; $p<0.05$) and it was correlated to the percentage organic material in the sediment (Pearson Correlation Coefficient = 0.853, $p<0.01$) (Figure 13). Abundance *Aulodrilus japonicus* was not correlated to the volume of transported sediment nor the per organic material in the section (Figure 14). *Pisidium* sp. abundance was significantly correlated to the organic material content (Pearson Correlation Coefficient = 0.716, $p<0.05$). Two of the most abundant taxa were not correlated to the volume of transported sediment nor to the percentage of organic material in the sediment (Tubificidae, Lumbriculidae, $p>0.05$ for all).

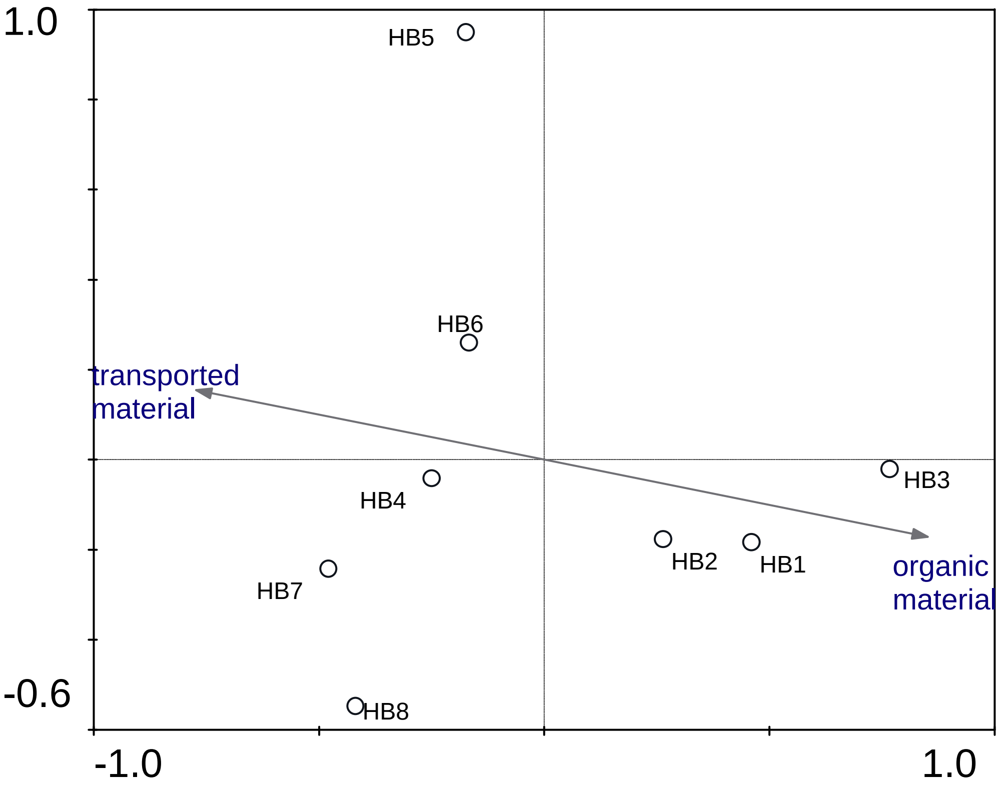

Figure 11: PCA ordination diagram – experiment 3 of the axis 1 (horizontal) and axis 2 (vertical), for stream sections 1-8. HB is an abbreviation of the name of the stream (Heelsumse stream). Arrows indicate environmental variables, which are used in the analysis as supplementary variables.

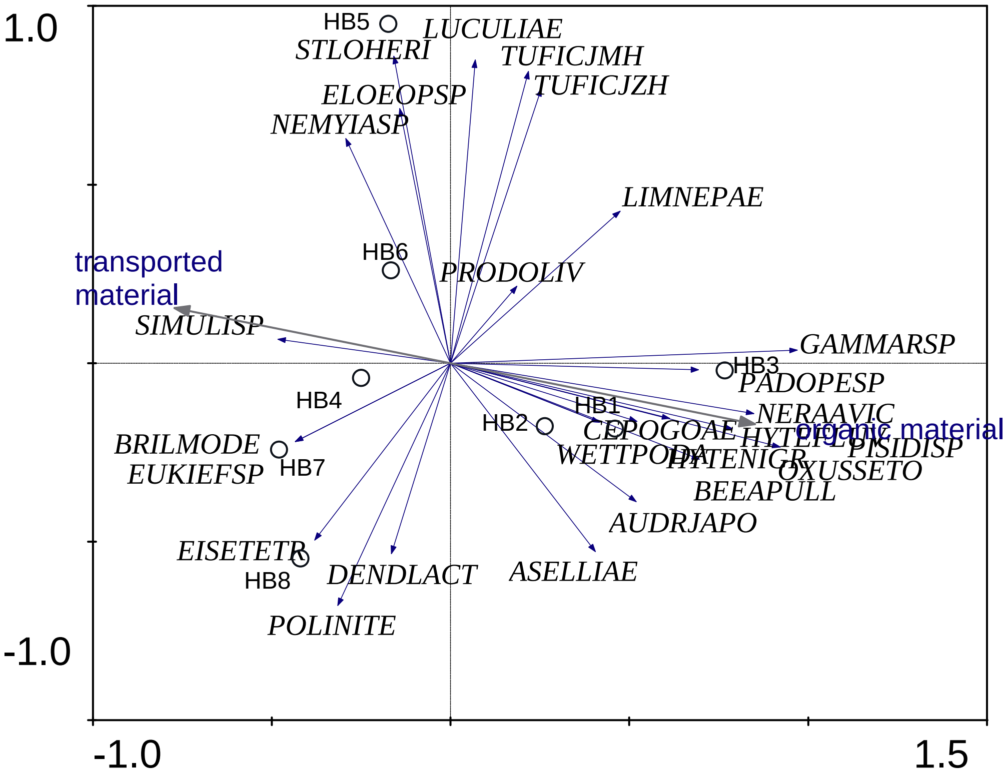

Figure 12: PCA ordination diagram of the axis 1 (horizontal) and axis 2 (vertical) of the samples-species relationship. Arrows indicate environmental variables, which are used in the analysis as supplementary variables. See appendix 2 for abbreviations of the taxonnames

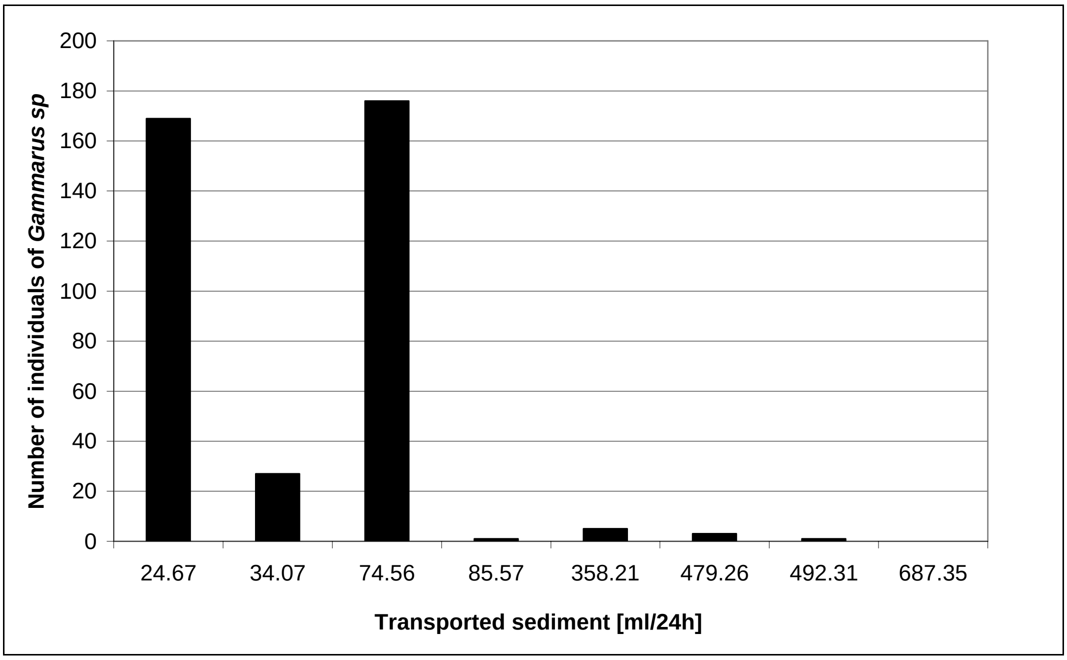

Figure 13: Heelsumse stream – experiment 3. Abundance of *Gammarus* sp. in relation to the volume of transported sediment.

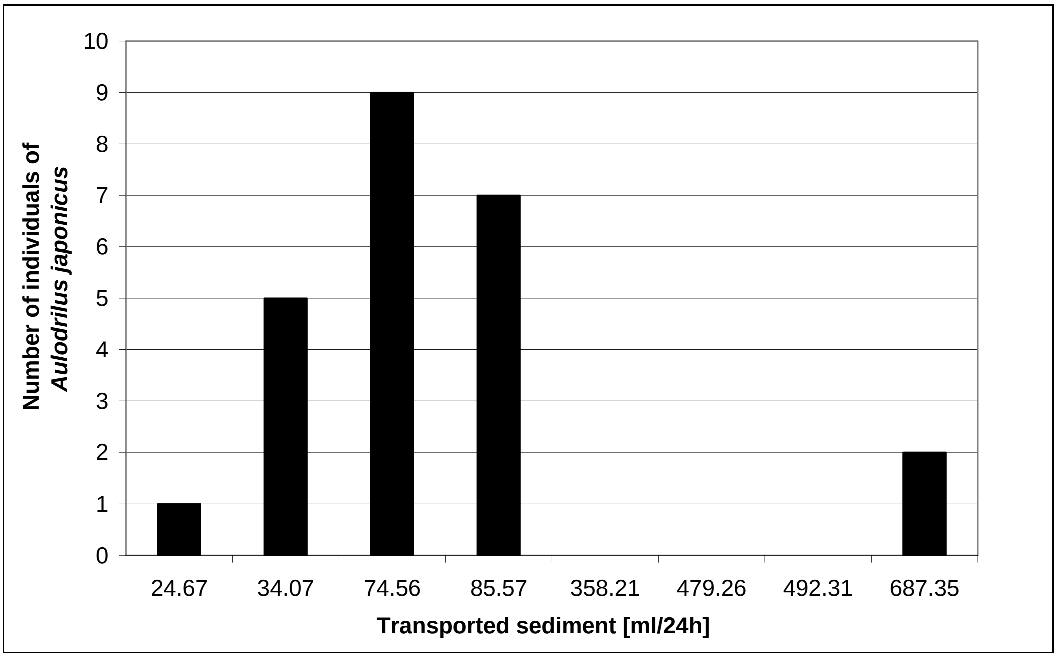

Figure 14: Heelsumse stream – experiment 3. Abundance of *Aulodrilus japonicus* in relation to the volume of transported sediment.

4 Discussion

4.1 Springendal stream

The strong correlation between amount of transported sediment and relative amount of organic material in the sections indicates that the more disturbed the substrate, the less organic material is available in that section. More disturbed areas could be less attractive for invertebrates for three reasons – (1) higher chance of being displaced, (2) less food available and (3) smaller number of shelters. The distribution of individuals and taxa in our experiment supported this hypothesis. It appeared that a number of invertebrates is influenced by rate of disturbance as well as the amount of organic material available. Samples from the areas with high sediment transport and low organic material content had a different macrofaunal composition compared to samples with low sediment transportation and a high organic material content. Depsite these factors, there was an additional factor influencing macroinvertebrate community composition, which is shown by distribution of samples along the second canonical axis.

Abundance of three most abundant taxa in the samples, *Polypedilum scalaenum*, *Gammarus* sp*,* and *Sericostoma personatum,* was clearly higher in the relatively stable sections and decreased with the amount of transported sediment and decreasing organic material availability. Swimmers like *Gammarus* sp. may avoid instable areas since they have no mechanisms of attachment. Probably, the risk of being unintentionally replaced by the moving sediment is higher for *Gammarus*. This species is also associated with packages of detritus where it can feed and find a shelter (Holomuzki, 1990), which may explain its choice for areas with a lot of organic material. *Polypedilum scalaenum* and *Sericostoma personatum* are detrivores (Foote, 1983; Coffman, 1984; Wagner, 1991). Therefore, one of the reasons for a higher abundance in stable habitats could be the relatively high organic material content of those areas. Additionally*, Sericostoma personatum* spends the day buried in the sediment (Wagner, 1991), thus its dominance in the stable sections may be caused by active selection of those areas, since in instable ones it can be easily uncovered due to sediment movement. The abundance of *Eloeophila* sp. was significantly correlated to both the stability of the sediment and availability of organic material. Perhaps the organic material content, where abundance of potential prey is high, is more important for this carnivorous animal than the sediment instability (Reusch, 1997).

Only two taxa did not show any preferences for the stability of the sediment - Tubificidae sp. with hair setae and *Dugesia gonocephala.* It is possible that members of the family Tubificidae are less sensitive to disturbances of the sediment. As burrowers, they can possibly react to unstable conditions by moving deeper into the sediment. Our sampling method allowed us to sample the substrate and invertebrates as deep as 2 cm, therefore Tubificidae that were present in the top 2 cm layer of the sediment were sampled, individuals present at greater depths were not sampled. *Dugesia gonocephala* moves over the sediment and as they live on the sediment – water line, they could be adapted to oppose disturbances. Still, it would be interesting to measure which magnitude of disturbance, if any, would force *Dugesia* to choose more stable habitat.

The difference in preferences of two species belonging to the same functional group is noticeable. *Polypedilum scalaenum* and *Dugesia gonocephala* are both climbers/clingers (Coffman, 1984), nevertheless *P. scalaenum* prefers stable conditions, while *D. gonocephala* was found also in areas with bigger instability of the sediment. This difference may be caused by the food sources they utilize. Herbivorous *P. scalaenum* chose areas with higher organic material content, while the carnivorous *D. gonocephala* can be found searching for the prey in all sections of the stream bottom.

4.2 Heelsumse stream

Taxon composition in the samples appeared to be associated with the volume of transported sediment and the percentage organic material of the sediment. Samples 1-3 were most similar, probably due to the small amount of sediment transported and high organic material content in these areas. Percentage of organic material in the sediment was not correlated to the volume of transported sediment in that section. This can be the result of a small percentage of organic material in areas with little sediment transport (section 2 and 4), probably caused by disturbances that could have occurred in these areas in the past. Like in the second experiment, there is one area which is characterized by a high Oligochaeta abundance.

Total number of individuals was not correlated to the amount of transported sediment nor organic material in the section, indicating that there appears to be no preference for the stability of the sediment. However, the number of taxa was significantly correlated to the amount of transported sediment as well as to the relative amount of organic material. Possibly, abundance of some dominant taxa could influence the abundance results.

Two out of five most abundant taxa showed a significant correlation to the organic material content of the area. Correlation of *Gammarus* sp with the amount of organic material is not surprising, since detritus is the main foodsource and serves as a refuge for this genera (Holomuzki, 1990). *Gammarus* sp. was basically absent in sections with high sediment transport and a low percentage of organic material, possible because there is less food available and animals are more exposed, resulting in a higher chance of being dislocated or damaged by the shifting sands. *Pisidium* sp. was correlated only to the organic material content of the sections. A possible explanation is that in these sections more suspended material is present in the water, the main food source of these organisms, because of reduced flow. Abundance of *Aulodrilus japonicus* was not correlated to the amount of transported sediment nor organic material in the sections, nevertheless *Aulodrilus japonicus* did not occur in the unstable sections with exception of 2 specimens in one section. Its preference to the areas with higher organic matter content has been shown by Verdonschot (2001). However, as shown in our experiment, distribution of the species in these streams depended not only on the organic material content, but also on the local stability of the sediment.

No preferences for the stability or organic material content were shown by two families of the Oligochaeta: Tubificidae (with hair setae) and Lumbriculidae. As in the previous experiment, lack of preference of Tubificidae (with hair setae) and Lumbriculidae for certain conditions can possibly be explained by a low sensitiveness to disturbances or by their ability to move deeper into the sediment as a reaction to unstable conditions. It is interesting that Tubificidae did not occur in higher numbers in the stable and unstable sections, but at the same time *Aulodrilus japonicus*, which also belongs to this family, was clearly more abundant in the stable sections. This points out the importance of identifying organisms to the lowest possible taxonomical level, because it is possible that within the families Tubificidae and Lumbriculidae, there are several species which have a clear preference for stable or unstable conditions.

5 Conclusions

Abundance and taxon composition of macroinvertebrates differed when areas with low sediment transport and a high percentage of organic material in the sediment were compared to areas with high sediment transportation and a low organic material content of the stream bed. Nevertheless, this is not the case for all species; preference of taxon specific and appears to be related to their functional characteristics. Especially swimmers and herbivores/detrivores preferred stable conditions, where they can find food, shelter and are less at risk of being replaced. Little response to the instability of the sediment was shown by the burrowers. Organisms belonging to this group probably have certain adaptations to survive in shifting sands. Among clingers/climbers we found species that clearly preferred stable conditions (*Polypedilum scalaenum)* as well as species that were present under both conditions (*Dugesia gonocephala*). This was possibly caused by a difference in resource use. The predator *Eloeophila sp* was found mainly in stable areas in the second experiment, while in the third experiment it showed no clear preference for sections with a stable sediment.

We can conclude that a sudden increase of discharge in sandy lowland streams, leading to increasing substrate instability, can reduce the amount of sediment surface area suitable for many abundant macroinvertebrate taxa. This may have important consequences for ecosystem functioning, for example organic matter processing

Literature

Carpenter R., Fisher S.G., Grimm NB, Kitchell, JF. (1992). Global change and freshwater ecosystems. Annual review of ecology and systematics 23: 119-139.

Coffman W.P. & L.C. Jr. Ferrington (1984): Chironomidae. In: An introduction to the Aquatic Insects of North America, Merritt R.W., Cummins K. W. (eds) (1984), Dubuque: Kendall/Hunt Publishing Company

Foote, B.A. (1983) Chironomidae. In: Immature Insects, Stehr F.W. (1983), Dubuque: Kendall/Hunt Publishing Company

Gasith A. & V. H. Resh; (1999): Streams in Mediterranean climate regions: Abiotic influences and biotic responses to predictable seasonal events. Annual review of ecology and systematics, 30: 51-81.

Holomuzki, J. R. & J. D. Hoyle, (1990): Effect of predatory fish presence on habitat use and diel movement of the stream amphipod, Gammarus minus. Freshwater Biology 24: 509–517.

McCabe, D.J. & N.J. Gotelli; (2000): Effects of disturbance frequency, intensity, and area on assemblages of stream macroinvertebrates; Oecologia; 124: 270-279.

Poff, N.L., Allan, J.D., Bain, M.B., Karr, J.R., Prestegaard, K.L., Richter, B.D., Sparks, R.E., Stromberg, J.C.; (1997): The natural flow regime: a paradigm for river conservation and restoration. BioScience, 47(11): 769-784.

Reice S.R., Wissmar R.C. & R.J. Naiman; (1990): Disturbance regimes, resilience, and recovery of animal communities and habitats in lotic ecosystems; Environmental management; 14(5): 647-659

Reusch, H. & P. Oosterbroek (1997): Diptera Limoniidae and Pediciidae, Short-palped Crane Flies. In: Nilsson, A (ed), Aquatic Insects of North Europe. A Taxonomic Handbook, Vol. 2: Odonata and Diptera. Stenstrup:Apollo Books

Verdonschot, P. F. M., 2006. Beyond masses and blooms: the indicative value of oligochaetes. Hydrobiologia 564: 127– 142.

Vieira, N.K.M., Poff, N.L., Carlisle, D.M., Moulton II, S.R., Koski, M.L., Kondratieff, B.C.; (2006): A database of lotic invertebrate traits for North America: U.S. Geological Survey data series 187, U.S. Geological Survey.

Vlek, H., P. F. M. Verdonschot & R. C. Nijboer, 2004. Towards a multimetric index for the assessment of Dutch streams using benthic macroinvertebrates. Hydrobiologia 516: 173–189.

Wagner, R. (1991): The influence of the diel activity pattern of the larvae of *Sericostoma personatum* (Kirby & Spence) (Trichoptera) on organic matter distribution in streambed sediments – a laboratory study. Hydrobiologia 224: 65–70

Appendix

Appendix 1 Taxonomical adjustment and taxon codes used in the experiment 2

Taxon name before transformation	Total number of individuals	Frequency	Taxon name after transformation	Taxon code used during analysis
Dugesia gonocephala	26	9	*Dugesia gonocephala*	DUGEGONO
Valvata piscinalis	1	1	*Valvata piscinalis*	VALVPISC
Helobdella stagnalis	1	1	*Helobdella stagnalis*	HEBDSTAG
Tubifex tubifex	5	2	Tubificidae without hair setae	TUFICJZH
Tubificidae without hair setae	5	2	Tubificidae without hair setae	
Tubificidae with hair setae	65	6	Tubificidae with hair setae	TUFICJMH
Lumbriculidae	9	6	Lumbriculidae	LUCULIAE
Lumbricidae	1	1	Lumbricidae	LUMBRIAE
Asellus aquaticus	1	1	*Asellus aquaticus*	ASELAQUA
Gammarus pulex	585	11	*Gammarus pulex*	GAMMPULE
Hydroglyphus geminus	1	1	*Hydroglyphus geminus*	HYGLGEMI
Eloeophila sp	21	6	*Eloeophila sp*	ELOEOPSP
Euphylidorea/ Phylidorea sp	1	1	*Euphylidorea/ Phylidorea sp*	EUPHYLSP
Neolimnomyia sp	5	5	*Neolimnomyia sp*	NEMYIASP
Psychodidae	1	1	Psychodidae	PSYCHDAE
Ceratopogonidae	1	1	Ceratopogonidae	CEPOGOAE
Paracladopelma nigritula	3	1	*Paracladopelma sp*	PADOPESP
Paracladopelma sp juv	4	1	*Paracladopelma sp*	
Polypedilum scalaenum	1718	12	*Polypedilum scalaenum*	POPESCAL
Polypedilum sp juv	1	1	*Polypedilum scalaenum*	
Brillia modesta	1	1	*Brillia modesta*	BRILMODE
Limnophyes sp	1	1	*Limnophyes sp*	LIESSPEC
Parametriocnemus stylatus	1	1	*Parametriocnemus stylatus*	PAOCSTYL
Rheocricotepus fuscipes juv	1	1	*Rheocricotopus fuscipes*	RHCRFUSC
Rheocricotopus fuscipes	5	5	*Rheocricotopus fuscipes*	
Prodiamesa rufovittata	15	6	*Prodiamesa rufovittata*	PRODRUFO
Chrysops sp	2	1	*Chrysops sp*	CHSOPSSP
Sericostoma personatum	19	6	*Sericostoma personatum*	SETOPERS

Appendix 2 Taxonomical adjustment and taxon codes used in the experiment 3

Taxon name before transformation	Total number of individuals	Frequency	Taxon name after transformation	Taxon code
Dendrocoelum lacteum	7	5	*Dendrocoelum lacteum*	DENDLACT
Polycelus nigra/tennis	12	5	*Polycelus nigra/tennis*	POLISSPE
Pisidium sp	32	6	*Pisidium sp*	PISIDISP
Pisidium casertanum	1	1	*Pisidium sp*	
Tubificidae with hair setae (not Aulodrilus)	67	5	Tubificidae with hair setae (not Aulodrilus)	TUBIAEJM
Tubificidae without hair setae	3	2	Tubificidae without hair setae	TUBIAEJZ
Aulodrilus japonicus	24	5	*Aulodrilus japonicus*	AUDRJAPO
Lumbriculidae	28	7	Lumbriculidae	LUCULIAE
Stylodrilus heringianus	3	1	*Stylodrilus heringianus*	STLOHERI
Eiseniella tetraedra	1	1	*Eiseniella tetraedra*	EISETETR
Oxus setosus	3	3	*Oxus setosus*	OXUSSETO
Hygrobates fluviatilis	3	2	*Hygrobates fluviatilis*	HYTEFLUV
Hygrobates nigromaculatus	5	2	*Hygrobates nigromaculatus*	HYTENIGR
Asellidae juv	4	3	Asellidae	ASELLIAE
Proasellus meridianus	8	4	Asellidae	
Gammarus sp juv	370	7	*Gammarus sp*	GAMMARSP
Gammarus pulex	12	3	*Gammarus sp*	
Nemoura avicularis	2	2	*Nemoura avicularis*	NERAAVIC
Neolimnomyia sp	2	2	*Neolimnomyia sp*	NEMYIASP
Ceratopogonidae	1	1	Ceratopogonidae	CEPOGOAE
Paracladopelma sp juv	1	1	*Paracladopelma sp*	PADOPESP
Polypedilum sp juv	2	1	*Polypedilum sp*	POPEDISP
Orthocladiinae juv	1	1	Orthocladiinae	ORCLANAE
Brillia modesta	1	1	Orthocladiinae	
Eukiefferiella	1	1	Orthocladiinae	
Prodiamesa olivacea	4	2	*Prodiamesa olivacea*	PRODOLIV
Simulium	8	2	*Simulium*	SIMULISP
Beraea pullata	7	3	*Beraea pullata*	BEEAPULL
Limnephilidae sp juv	15	6	Limnephilidae sp	LIMNEPAE
Elophila sp	5	3	*Elophila sp*	ELOPHISP